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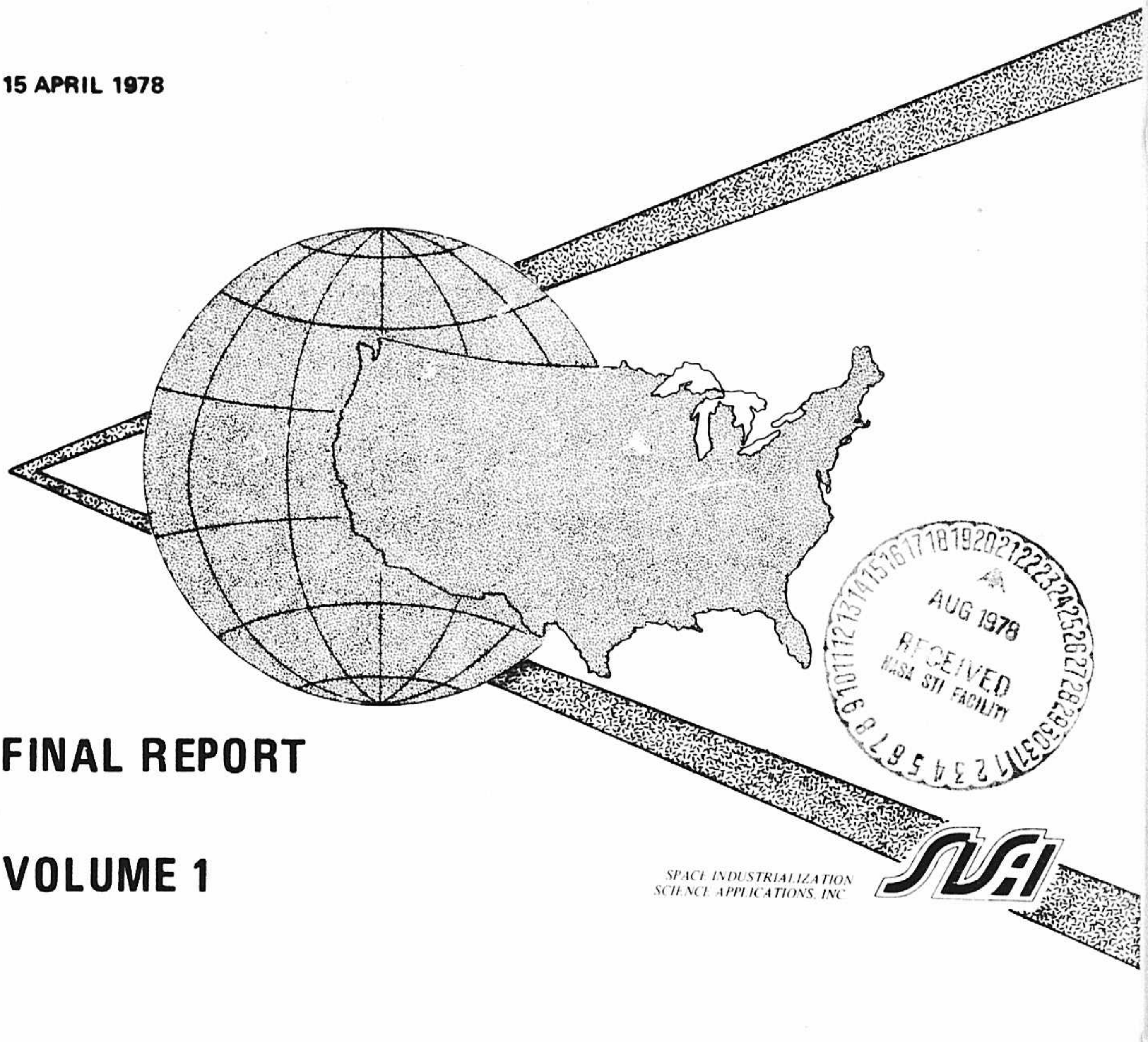

FINAL REPORT

VOLUME 1

SPACE INDUSTRIALIZATION
SCIENCE APPLICATIONS, INC

SAI-79-602-HU

SPACE INDUSTRIALIZATION STUDY

FINAL REPORT - VOL 1

SPACE INDUSTRIALIZATION - AN OVERVIEW

APRIL 15, 1978

PREPARED UNDER NASA CONTRACT NAS8-32197

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FOREWORD

This $198,962.00 Space Industrialization Study was performed under NASA Contract NAS8-32197 for Marshall Space Flight Center from September 1976 through April 1978. The study was in two parts: Part 1 identified the future opportunities for space industrialization, quantified the potential benefits and developed and analyzed evolutionary program options required to take advantage of these opportunities; Part 2 defined the framework of international governmental, industrial, legal and economic constraints within which space industrialization (SI) must evolve. Step-by-step guidelines to implementation of programs to capitalize on the SI opportunities were formulated using information from Part 1 and Part 2. The study results are documented in four volumes:

1. SPACE INDUSTRIALIZATION - AN OVERVIEW
2. SPACE INDUSTRIALIZATION - OPPORTUNITIES, MARKETS AND PROGRAMS
3. SPACE INDUSTRIALIZATION - WORLD AND DOMESTIC IMPLICATIONS
4. APPENDICES

Part 1 of the study was managed by Dr. Ralph Sklarew and Part 2 by Mr. Gerald W. Driggers. Other key SAI participants were Mr. E. Battison, Mr. D. Davis, Mr. Sam Gibson, Mr. Mark Klan and Mr. Gordon Collyer. A large portion of the work reported here was accomplished by consultants who occupied roles as principal investigators. The key consultants were:

- Mr. Robert Salkeld - System Planning and Programmatics
- Mr. G. Harry Stine - Industrial Planning and Marketing
- Mr. Paul Siegler - Market Assessment and Economic Analysis
- Dr. J. Peter Vajk - World Dynamics and Futures Assessment

A subcontract to Southern Research Institute (SoRI) in Birmingham, Alabama, was managed by Mr. Driggers during Part 1 of the study, prior to his joining SAI. Key participants at SoRI were Mr. S. J. Causey and Mr. R. Monroe.

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The study was performed under the technical direction of Mr. Rodney Bradford (Part 1) and Mr. Georg von Tiesenhausen (Part 2), Marshall Space Flight Center. Mr. J. von Puttkamer was the program manager for NASA Headquarters, Office of Space Transportation Systems.

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1. SUMMARY

Space Industrialization (SI) is the medium by which services, energy and products are returned from space to Earth to provide economic and other pragmatic benefits to mankind. Although this study focuses on the United States as the mechanism for benefit generation and transfer (with an appropriate payback to its industry and citizenry for investing resources and labor), it is the world that benefits. Indeed, the underdeveloped and developing countries are now, and will continue to be, prime beneficiaries from Space Industrialization. It is possible to construct credible scenarios which step these nations into the twentieth century equivalent of the U.S. in less than 100 years, without significant local or global economic or environmental damage. The great power for what is considered "good" in the western world (health, safety, knowledge, creative growth, etc.) afforded by Space Industrialization has been comprehended by a very few, but there is evidence that realization is spreading. It is hoped that this document and this report, in conjunction with the companion report by Rockwell International, will assist in this realization, and help promote early expansion of the beneficial returns on humanity's investment in space.

The SAI study concentrated on the U.S. and what we may gain from the investing of our resources, both public and private, in SI. The future was examined to characterize resource pressures, requirements and supply (population, energy, materials, food); also, the backdrop of probable events, attitudes and trends against which SI will evolve were postulated. The opportunities for space industry that would bring benefits to Earth were compiled and screened against terrestrial alternatives. Most survived, and a population of the survivors were examined to determine if SI would ever be "worth the investment". A cursory market survey was conducted for the selected services and products provided by these initiatives and the results were astounding. Space Industrialization is a billion dollar a year business now; in thirty years it could grow by 100 times that amount or more!

But, space is expensive. Might not the investment outweigh the gain? Programs of SI evolution corresponding to the postulated future scenarios were developed, and the investments compared to the revenues and their associated benefits. The program analysis results brought two observations: SI investments will be good investments and the sooner the investment, the better for all concerned (in terms of the pure mathematics). It was recognized, however, that certain other factors may control the practical rate of progress.

These "other factors" were examined to the extent practical in this study; a great deal remains to be done. The following observations are in order, however, based on this assessment.

(1) Foreign competition is becoming very strong in SI. It is no longer "our" domain and these pressures will increase. This may limit or spur U.S. increased involvement.

(2) The developing and underdeveloped nations of the world may consider the U.S. and SI a threat or a powerful tool for progress depending on how we promote it.

(3) Prospects for economic return to the government (public sector) are excellent, so long term investments should be justifiable. A few billion of dollars invested in the eighties will result in hundreds of billions in tax revenues, millions of jobs created, strong economic growth and good balance of trade impacts in twenty years or less.

(4) Although some U.S. industry will resist SI, a strong support base can be built among U.S. private enterprise.

(5) In both domestic and international law there are no legal entanglements which will seriously inhibit SI development, if we develop proper policies and stick to them!

(6) Although many social and political institutions will be affected by SI, the most significant are those institutions governing industry and government relations and those relating the U.S. to the rest of the world. Nothing precludes mutually beneficial arrangements in both of these arenas. Historically, such arrangements have taken several years to evolve.

(7) The most important SI initiatives would appear to have rather high initial investments, and payback periods longer than normal for private investment. A mechanism for reducing initial risk and shortening these payback times is possible and will attract substantial industry support upon initiation.

Thus, in sum, this study has concluded that Space Industrialization exists and substantial and sustained growth is highly desirable. From examination of the SI programs and their characteristics the following recommendations were drawn.

(1) Strong industry involvement in all areas of SI from planning to ultimate operations is necessary to return maximum benefits.

(2) A central group, perhaps under the Administrator of NASA, especially tasked to plan, integrate and advocate SI activities is needed badly. Such a group, located within the government, may indeed be essential if private enterprise can not meet the challenge on its own.

(3) Space Industries will need 25 to 75 KW of raw power in the early-to-mid-eighties, 100 to 500 KW in the latter eighties and 1-10 MW in the early to mid-nineties. A Solar Power Satellite prototype development program to prove technical/economic feasibility and environmental acceptability would have similar milestones and characteristics. Space power needs for products have a similar progression, with the possibility of a three to five year lag in demand relative to other requirements. A space power program designed to integrate and synergize these requirements should be initiated, beginning with development of the 25 KW Power Module currently proposed. The requirements for a concurrent large structures program is implicit to the power program.

(4) The cost of space transportation to low Earth orbit must come down below shuttle projections by a factor of 10 to 100 to really open the products market in the nineties. The Shuttle is the key, but the longer term SI requirements are already apparent. Increases in flexibility and decreases in cost are needed by high orbit operations in the latter eighties for both services and energy initiatives. Propulsion and vehicle programs to meet these needs should be integrated into future transportation planning.

(5) The U.S. (probably through the NASA) should embark on an intensive data gathering and planning effort during FY 79, 80 and 81 in parallel to initiation of early projects such as 25 KW Power Module. This effort would culminate in a carefully coordinated, evolutionary Space Industrialization Plan with domestic and international as well as government and industry segments.

The above recommendations imply only modest budget commitments over the next three years (less than five million per year in studies and planning and less than fifty million per year in hardware commitments). The budget requirements for development and implementation of initiatives with early direct returns (mid to late eighties) plus long lead technology development for the nineties has a funding peak of less than four billion dollars annual. That cost could be shared in various ways between NASA, other government agencies, private industry and international (or foreign) organizations. The space technology peculiar funding requirements are less than two billion of the four billion total.

A great deal of work remains before Space Industrialization enters the main stream of government and industry planning, and a proper public understanding is achieved. A solid information base, a dedicated advocacy group and very hard work are the essential ingredients to accomplishing these objectives. The rewards will be worth the effort, and attaining these goals will turn Space Industrialization into the mechanism for achieving the next plateau of human development.

The remainder of this document provides discussion in greater depth in the tasks of the study as outlined in the Summary. Volumes 2, 3 and 4 of this report contain the in-depth discussion and data.

2. THE TERRESTRIAL BACKGROUND FOR SPACE INDUSTRIALIZATION 1980 - 2010

During the next few decades, space technology (developed for purely scientific reasons, for political and prestige reasons, or to serve specific military needs) can be adapted, extended, and expanded to use the new environment and nearly limitless resources of outer space for the benefit of humanity in an economically profitable manner. Space industrialization will then grow from a handful of commercially operated communications satellites into a highly diversified and expanding sector of the human socioeconomic system. In the first few decades, however, it will necessarily depend for its very existence on the conventional segments of the socioeconomic system to provide the technology, the original investment capital, and the markets for its goods and services. Thus it is essential to explore the nature and shape of the socioeconomic system as it may evolve in the next few decades before we can realistically examine just what may constitute space industrialization, and how, why, and when portions of the new space industries may arise.

This examination of the terrestrial background has been done in two parts. First, basic macroeconomic projections were made to examine the needs of the human socioeconomic system during the coming decades with respect to basic materials: energy fuels, minerals, and basic agricultural commodities. If the "limits to growth" hypothesis should prove to be correct, then perhaps space industrialization could provide some of the very basic needs of the industrialized societies of the world. Second, a variety of alternative futures were examined to determine how space industrialization might be shaped by events and developments in the rest of the system. The economic profitability, political viability, and social desirability of specific space industrial activities can only be defined in the context of general social, political, economic, and technological factors characterizing an alternative future. These alternative future scenarios also provide some basis for contingency planning and for identifying stepping stones in space technology which are most likely to be useful in any future space programs or activities.

The results of these two parts of our examination of the terrestrial background provided some of the basis for considering the market potentials of various possible space industries and much of the foundation for developing specific examples of possible programs of space industrialization during the next few decades. The necessity for continuous planning of intermediate and long range programs became quite clear from this work. Just as buggywhip manufacturers who did not foresee that self-propelled trucks would make the horse-drawn milkwagon obsolete were soon reduced to financial ruin, proponents of specific possibilities for industries in space may find themselves stranded by changes in the terrestrial background due to new economic, political, social, or technological factors unless they continually dedicate some effort to planning their programs in relation to current developments and trends on Earth.

2.1 RESOURCES ASSESSMENTS

A detailed assessment (case-by-case) of natural resource availability (described in Vol. 2) was made for 18 minerals selected either because of their large volume (such as iron) or because of critical importance to important industrial processes or agriculture (such as phosphate). Fossil fuels were also examined in assessing likely sources of energy in the next three decades. But to assess supply and demand for such commodities, it was necessary to project population growth and trends in basic economic indicators such as GNP and personal incomes. In addition, we have examined the outlook for a number of basic agricultural commodities, albeit in a somewhat simplistic manner.

2.1.1 Conclusions

It does not appear, on the basis of our examination of energy, minerals, and food production issues over the period 1980 to 2010, that any of these will pose any critical threat to the survival of industrial civilization. The spectre of impending scarcities does not, therefore, provide a credible basis for the political support necessary to mount a major thrust into space at public expense on a crash program schedule. The importance of long-range solutions to the problems of energy supply, however, is clear in the discussion above. The economic value of energy and minerals imported from space may be significant and may provide sufficient motivations for space industrialization; these possibilities should not be dismissed lightly. But their justification, during the period of interest in this study, must be found elsewhere. "Limits to growth" cannot justify space industrialization during the next three or more decades.

2.2 CONSTRUCTION OF ALTERNATIVE SCENARIOS

We have selected a list of ten events or developments which appear to have a reasonable chance of occurring in the next two or three decades and which would be likely to have major effects on the shape of the future. Arranged according to morphological categories, these "triggering" events or developments are as follows:

Extrapolative:

Baseline (for comparison-no "triggering events")

Political:

Major advances in space by other nations.
U.S. commitment to space.

Societal:

Major breakthrough in human longevity.
U.S. disenchantment with space.

Economic:

Entrepreneurial exploitation of space technologies.
Artificial shortages of critical minerals.
Economic collapse due to shortage of capital.

Technological:

Breakthrough in a new energy source.

Environmental:

Human-generated ecological catastrophies.
Rapid cooling of the Northern Hamisphere.

2.2.1 General Observations

The scenarios described here span a wide range of possible futures. While opportunities for the advocacy of a variety of specific space industrialization activities appear in every scenario, many of these opportunities are apt to fall in the private sector rather than in NASA or other governmental agencies. Because of the strong possibilities of synergisms between various space activities, however, NASA can no more ignore private sector activities and developments than the private sector can ignore NASA plans for development of new launch vehicles. If NASA's efforts are to have the greatest benefit, those efforts must be based on up-to-date understanding of the opportunities for advocacy presented to the private sector and to the whole public sector by developments in the human system as a whole. This requires *continuous* examination by NASA of the changing opportunities and of the changing fabric of the human system. Planning space industrialization cannot be done effectively if it is done only in fits and starts; the volatility of the human system requires reassessment of alternative futures on a continuing basis to identify, at each moment, what space systems and space technologies are most likely to be used by a wide variety of space industrialization opportunities. *Just as short-range planning is done on a continuing, day-to-day basis, mid-and long-range planning must be done continuously to prepare for contingencies.*

3. INDUSTRIAL OPPORTUNITIES IN SPACE

The establishment of future markets and a space industrialization program for each future scenario required a compilation of potential opportunities. These were established to a level of detail and breadth of application sufficient to allow gross market survey and preliminary program formulation.

The purpose of this compilation was not to create an exhaustive shopping list of opportunities but rather to key in certain indicative possibilities within each industrial activity identified (Information Services, Energy, Products, People). The goal was of sufficient breadth to insure represensative program formulation and appropriate market survey. The result of this is a compilation of over 200 potential applications for space related goods and services.

As previously noted, the opportunities and their identified representative usage were compiled under four industry activity categories: Information Services, Energy, Products and People (in space). Each of these categories was further subdivided into subcategories as follows.

<u>Information Services</u>

Communications
Observations
Navigation
Location
Sensor Polling

<u>Energy</u>

Solar Power Satellite
Redirected Isolation
Nuclear Waste Disposal
Nuclear Power/Breeder Satellite
Power Relay

<u>Products</u>

Biologicals
Electronics
Electrical
Structural
Process
Opticals

<u>People</u>

Tourism
Medical
Entertainment/Art
Recreation
Education
Support

4. THE TERRESTRIAL ALTERNATIVES

Thirty-two candidates for space utilization were compared to potential Earth based alternatives. Comparisons were based on examining the initial cost of installation on a first order basis and a cursory review of qualitative factors such as ease of use, reliability, technology requirements, etc. If costs and capability obtained appeared comparable between the alternatives, they were retained for further study. In certain instances the identified space uses exhibited much lower cost for similar capability or the reverse. These were identified as clearly viable candidates. Where cost and/or capability were clearly superior for the Earth alternative, the candidate was dropped from further consideration.

For five of the thirty-two the terrestrial alternative was deemed clearly superior, seven appeared more favorable accomplished from space and twenty depended too much on specific details (too close to call).

The generic lessons culminate with the conclusion that alternatives do exist, or can be visualized for most space initiatives. "Uniqueness" of the space candidates detailed was not deemed strong enough to warrant special consideration in a competitive environment. Significant technological "lead" for space options was found only in the area of earth resources. And, in the case of communications, implementation may be tipped already toward terrestrial options. In concert with these arguments it is concluded that market softness, in terms of systems requirements, remove the constraint that terrestrial alternative systems must duplicate exactly space products and services.

The implications of the above statements gives rise to the following observations on the viability of terrestrial alternatives.

1) Complexity from detailed assessment of non-cost issues substantially reduces the opportunity to develop a "winning" mix of space efforts based on generalized benefits.
2) In lieu of a mandate, space viability must be aggressively advocated/studied against competitors in the mid 1980's.

3) The current involvement of an existing industry will typically indicate which alternative would be favored by it unless forced by competition to change directions. New entries in an industry will select a path based on investment and risk considerations. Most space initiatives considered in this study will appear highly favorable over terrestrial alternatives only after steps toward risk reduction are implemented.

5. POTENTIAL MARKETS AND REVENUES

5.1 APPROACH

After compilation of the list of Industrial Opportunities was complete, a review process was undertaken to select initiatives for preliminary market analysis. The primary criteria applied in the screening process were availability of data and probable advantage over terrestrial competitors. Assumptions were made based on the data available after the analysis was underway.

Different specific methodologies were applied according to which industry was being examined. For example, market analyses for Products were much more speculative than those for Information Services since much less is known about the specific use and probable cost of a prospective product. A common set of general methodology guidelines were used wherever appropriate and provide the foundation for understanding the philosophy and assumptions which guided these market surveys.

5.2 AGGREGATION OF MARKET POTENTIAL

One conclusion quickly drawn from the data derived in these analyses is that very large single opportunity revenues are possible in several areas. It follows that aggregates of these potential (or expanded) industries will represent even great possibilities.

As indicated in each market analysis the flow of revenues initiates and evolves based on several assumptions including best case/ least case for total market potential at saturation. Thus the actual revenues which might be anticipated in the time period of this study will depend substantially on the background scenarios previously presented. For purposes of analyzing far and near term implications of space industrialization, the time frame of initiation and rate of growth of each industry was adjusted during the analysis.

Although the more exact figures will depend on such specifics as future scenarios and programmatics, it is worthwhile to summarize revenue projections. This will allow interpretation by the reader of the possible significant of SI in the 1980 - 2010 time period. Summary data are presented below for revenues (best case). The timing shown is considered to correspond roughly to the baseline scenario. All revenues calculated are additive to current SI revenues which total about one billion dollars per year in 1978.

The relative value of each market area (Information Services, Energy, Products and People) as a function of time is presented in Figure 5-1. A more aggressive scenario (implying more aggressive SI programs) basically accelerates the revenue flow and adds more minor initiatives. A scenario without SPS eliminates that portion of the summary and inhibits other activities in the Information Services and Products industries. In the opinion of the SAI study team, given no "surprises", no substantial foreign challenges in space, etc., we can expect space industrialization to evolve as depicted in Figure 5-1.

Inherent to this prediction is a period of capability and technology development in the 1980s leading to expanded exploitation and utilization in the 1990s and intensive growth beyond the year 2000. The resulting interpretation from this is that revenues will approximately double from 1980 to 1990. A very rapid growth in revenue then ensues as technology and hardware development efforts in the eighties come on line in the 1990 to 1995 time period. Although new technologies (particularly in power, structures and transportation) are emerging, the activities settle basically into an implementation and expansion phase with doubling time for revenues becoming approximately five years until the end of the time period of interest.

There appear to be no "natural laws" or technological barriers which would limit revenue growth to the level indicated. Strong response to a foreign challenge or a heavy entrepreneurial initiative in the near future (early eighties) could result in more rapid growth. Potential revenues well over 100 billion (1977) dollars per year appear feasible with technology and development effort acceleration and aggressive marketing.

PROJECTED ANNUAL AND CUMULATIVE REVENUE POTENTIAL FOR SELECTED INFORMATION SERVICES INITIATIVES (1977 DOLLARS)

	POTENTIAL REVENUES (in Millions of Dollars)	
	ANNUAL (PEAK)	CUMULATIVE (1985 – 2010)
INFORMATION SERVICES		
Pocket Telephone	20,000	100,000
Teleconferencing	9,000	90,000
National Information Services	6,000	40,000
Electronic Mail	9,000	90,000
Disaster Communications Set	30	500
Advanced TV Broadcast	2,000	8,000
Vehicle Inspection	300	4,000
Global Search and Rescue	50	300
Nuclear Fuel Locators	3	40
Ocean Resources	2	50
Transportation Services (Equipment Sales)	70	400
Rail Anti-Collision System	40	600
Personal Navigation Sets (Equipment Sales)	100	400
Vehicle/Package Locator	300	5,000
Voting/Polling Wrist Set	40	200
	~ $47B/YEAR	~$340 BILLION

PROJECTED ANNUAL AND CUMULATIVE REVENUE POTENTIAL FOR SELECTED ENERGY INITIATIVES (1977 DOLLARS)

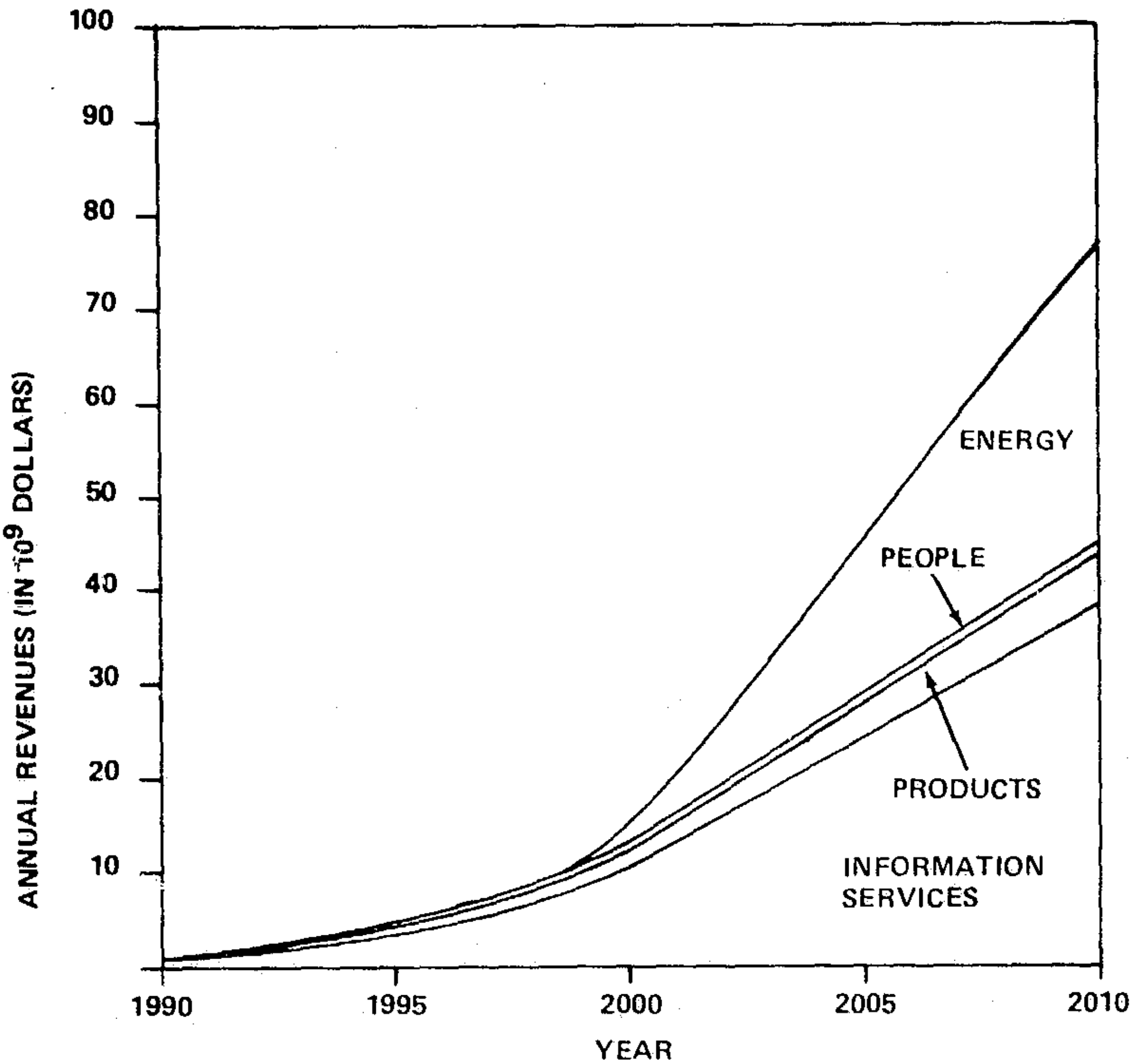
	POTENTIAL REVENUES (in Millions of Dolars)	
	ANNUAL (PEAK)	CUMULATIVE (1985 – 2010)
ENERGY		
Solar Power Satellite (First SAT in 1996)		
49 5GW at 27 MILS/KWH	50,000	300,000
60 10GW at 11.5 MILS/KWH → 7.1 MILS/KWH	30,000	200,000
60 10GW at 27 MILS/KWH	100,000	600,000
Urban Night Illuminator	200	2,000
Nuclear Waste Disposal	1,000	3,000
	~$30 – $100 B	~$200 – $600 B

PROJECTED ANNUAL AND CUMULATIVE REVENUE POTENTIAL FOR SELECTED PRODUCTS (1977 DOLLARS)

	POTENTIAL REVENUES (in Millions of Dolars)	
	ANNUAL (PEAK)	CUMULATIVE (1985 – 2010)
PRODUCTS		
Drugs and Pharmaceuticals	600	7,000
Electronics		
Semiconductors	2,000	20,000
Electrical		
Magnets	300	4,000
Superconductor (generating only)	2,000	20,000
Optical		
Fiber Optics	80	800
Special Metals		
Perishable Cutting Tools	800	8,000
Bearings and Bushings	200	2,000
Jewelry	100	2,000
	~ $6 B/YR	~ $64 BILLION

PROJECTED ANNUAL AND CUMULATIVE REVENUE POTENTIAL FOR SELECTED PEOPLE INITIATIVES (1977 DOLLARS)

	POTENTIAL REVENUES (in Millions of Dolars)	
	ANNUAL (PEAK)	CUMULATIVE (1985 – 2010)
PEOPLE		
Space Tourism	50	900
Space Hotel	50	600
	~ $100 M/YR	~ $1.5 BILLION



Note: All values shown are additive to the present (1977) revenues of approximately one billion dollars per year. All Figures are in 1977 dollars.

Figure 5-1. Project Revenues for Space Industry Activities Assuming the Baseline Scenario for Terrestrial Background

6. SPACE INDUSTRY PROGRAM DERIVATION AND ANALYSIS

The results of the work described in previous sections (Terrestrial Background, Opportunities and Markets) provided the basic information necessary to map out probable courses of future programs. Space Industrialization by definition consists of a multitude of development or operational programs occurring simultaneously or in series. In the first part (Part 1) of this study, the totality of programs was referred to as a "program" for convenience. That terminology has been maintained in this volume in order to distinguish these "program" analyses from the work in Part 2 of the study. In Part 2, SAI and Rockwell Int. agreed to change the semantics so that the word "Plan" represented the totality of programs.

The flow and interrelationship of various tasks from which programs were derived and analyzed is shown on Figure 6-1 which also summarizes the grouping of eleven scenarios into six programs. The philosophy of this grouping is discussed in Volume 2.

The hypothetical programs we have developed reflect our considered collective judgment of what kinds of space activities are likely to be economically and politically viable in the assumed contexts of the background scenarios. Like the scenarios themselves, these programs should not be interpreted as attempts to forecast the future but rather as explorations of plausible alternatives which can be used to provide reasonable guidelines for long-range planning. This kind of exploration can serve to identify stepping stones which are common to a multitude of alternative futures and to identify systems which are likely to be much more dependent on external contingencies, requiring more careful attention to the course of events.

To scope future costs, impacts and requirements, three programs were selected for detailed analysis. These were the Baseline, No SPS and Upside Programs. The procedure was to take the general programs and just specific timing and scale according to guidelines from the scenarios

CONSOLIDATION 11 SCENARIOS → 6 PROGRAMS	
Foreign Challenge Commitment to Space Longevity Breakthrough	Upside
Cooling of N. Hemisphere	Climatic Crisis
Space Entrepreneurs	Commercial
Baseline Critical Materials Shortage Ecological Catastrophes	Baseline
Energy Breakthrough	No SPS
Disenchantment with Space Collapse of Debt Structure	Downside

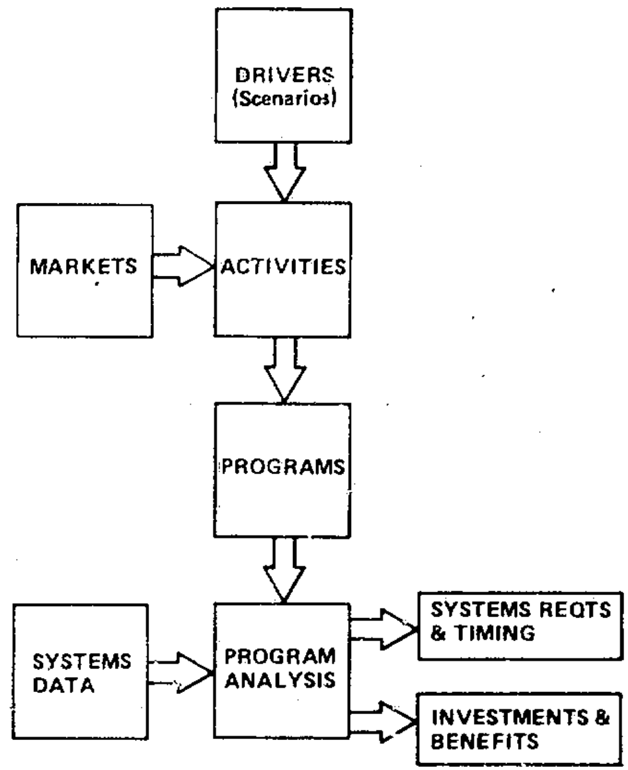


Figure 6-1. Summary of Space Industry Programs Derived and the Steps to Their Derivation and Analysis

and market data. In some cases several initiatives were lumped into a single system for purposes of simplifying costing and scheduling. A platform approach to developing the communications initiatives was assumed.

Introduction and growth of the various Information Services leads to requirements for very large platforms in the nineties and beyond corresponding to the market projections presented previously. This turned out to be the largest single set of industry initiatives in terms of power and structures other than SPS and light reflectors.

The results of the program analysis in terms of structure, power and transportation needs is shown in Figures 6-2 and 6-3.

ACTIVITY	INFORMATION	ENERGY	MATERIALS	PEOPLE
MAJOR SPACE ADVANTAGE	• VIEW • ACCESS	• SOLAR FLUX	• LOW 'G' HIGH VAC • HIGH VAC	• UNIQUENESS
MAJOR TECHNICAL HURDLES	• SIZE 10–100 METER ANTENNA • POWER 21 KW – 10,000 KW • DATA PROC • TRANSPORT COST (OPERATIONS)	• SIZE/MASS OF SYSTEM $\sim 10^4$ MW $\sim 10^5$ TONS $\sim \$10^{10}$ • TRANSPORT COST $<$ \$20/LB LEO • ENVIRONMENT ISSUES	• PROOF OF THEORY • PRODUCTION DEVELOPMENT HUNDREDS OF POUNDS PER DAY • POWER 10 KW – 10,000 KW CONTINUOUS • TRANSPORT COST $<$ \$100/LB LEO	• TRANSPORT COST \$25/LB OR LESS • HABITATION
TIMING FOR SIGNIFICANT REVENUES	• PRESENT $>$ \$1000 M/YR • 1985 + RAPID EXPANSION	• 1996 +	• 1987 +	• 1990 +

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Figure 6-2. A Summary of Qualitative and Quantitative Observations Drawn From the Programs Analysis

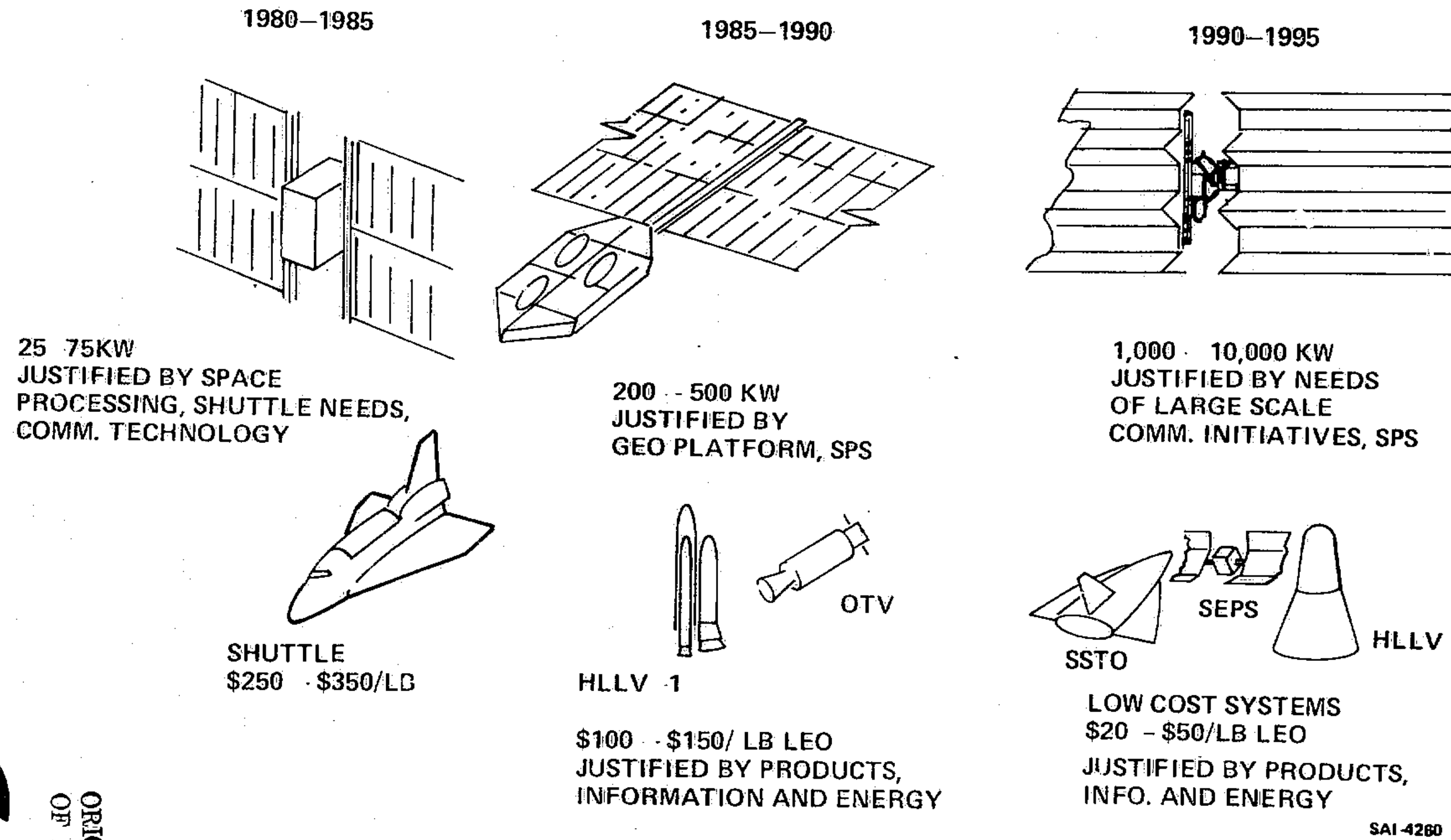

Figure 6-3. SI Structures, Power and Transport Requirements

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7. WORLDWIDE ACTIVITIES IN SPACE INDUSTRIALIZATION AND THEIR IMPLICATIONS

From military and scientific beginnings some twenty years ago (October 1957 for Sputnik, January 1958 for Explorer) there has evolved a broad and complex industrial base in space. The activities range from basic research in the space processing of materials to the fully operational information transfer systems. The worldwide gross annual revenue now exceeds one billion dollars in sales of services alone. Current published projections indicate that revenues from services by 2010 may reach ten to twenty billion dollars given only minor extrapolations of present technology. With technology advancements in power, structures, transportation, materials processing, frequency use and data handling our study indicates that the potential can be several times that revenue amount. Of the four general categories of space industrialization (Information Services, Products, Energy, People in Space) the area nearest maturity is Information Services. New technologies will be necessary to open up new markets in these services also, however.

The worldwide interest in SI is reflected by the number of countries and agencies that are actively participating at present. This is characterized in Figure 7-1 by summarizing capabilities both previously demonstrated and currently being developed that relate specifically to Space Industrialization.

Why is there such extensive involvement in organizing for and implementing Space Industrialization in the world? In the simplest terms, it appears that needs and markets exist forming the basis for large scale international involvements. This has prompted a wide spread interest and desire for independent capabilities to utilize space and an awareness of the potential benefits from gaining and maintaining a competitive position. In the free world the US will be challenged through the eighties in all technologies including those that are peculiar to manned space flight. The recent capability demonstrations of the USS aboard Salyut 6 and the strong reports of their current development of a reusable shuttle leave no doubt that major technical achievements can be anticipated by communist bloc countries in SI throughout the eighties.

	GENERAL				UNMANNED				MANNED				UNMANNED			MANNED			
NATION / CAPABILITY	DATA HANDLING	GROUND STATION(S)	LAUNCH FACILITY (S)	SUBORBITAL LAUNCH	LEO LAUNCH	LEO RETURN	GSO LAUNCH	ORBITAL RENDEZVOUS	LEO LAUNCH	LEO OCCUPANCY	ORBITAL RENDEZVOUS	ORB. PROPELLANT TRANS.	EARTH OBSERVATION	COMMUNICATIONS	NAVIGATION	TEST & EXPERIMEN.	MAINT. & REPAIR	REMOTE CONTROL	MATERIALS PROCESSING
UNITED STATES	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
USSR	X	X	X	X	X	X	X	ⓧ	ⓧ	ⓧ	ⓧ	ⓧ	X	X	X	ⓧ	ⓧ	X	X
CHINA (PR)	X	X	X	X	X	X							X	X					
FRANCE	X	X	X	X	X	?							X	X					X
INDIA	X	X	X	X	(X)								X	X					
JAPAN	X	X	X	X	X		X							X					
ESA	X	X	X	X	(X)		(X)			(X)			X	X		(X)			X
OTHER	X	X	X	X	X								X	X					X
TOTAL NUMBER OF NATIONS	111	39	24	15	9	3+	4	2	2	3	2	1	7	13	2	3	2	3	5

(X) Indicates to be demonstrated by 1981.
ⓧ Indicates currently unique capability
X Indicates capability has been demonstrated.

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Figure 7-1. Worldwide SI Capability Summary

8. DOMESTIC IMPACTS AND ISSUES

Space Industrialization (SI) will have impact and meaning in many areas of human endeavor in the United States as well as the world. These impacts may be more subtle than profound, given the level of economic and technical development already enjoyed by the U.S. Nonetheless, these impacts will be important and, indeed, can provide the stimuli necessary to assure U.S. economic growth through the last decade of this century and into the next. The realization of these impacts in a positive fashion will depend completely on establishment of government roles supportive to greatly enhanced private sector involvement in space.

8.1 EMPLOYMENT AND ECONOMY IMPACTS

The economic impacts examined in this study were based on an alternate approach to simple trend extrapolation. From the scenario, market and program work reported in Volume 2, it was surmised that significant opportunities existed in the near future in the public and private sector. If advantage is taken of these opportunities, a much greater benefit to the U.S. and world can be realized than would be predicted by simple trend forecasting. Thus the analyses whose results are presented here were structured to show what could happen, and hopefully help precipitate the required actions. As mentioned in the discussion on Future Scenarios (Volume 2), an implicit assumption in all analyses was that opportunities would be capitalized on, the extent of which varied between scenarios. This is reflected in the six programs developed and presented in Volume 2 and more specifically in the two programs analyzed in detail. The following benefit calculations are based on those analyses.

8.1.1 Assumptions

Certain assumptions concerning the nature of the industries involved in stimulating and handling the revenue flows were necessary. Composite indices were developed and applied across the board without specific variation between industry types, products vs. services, etc.

Given the composite nature of the expenditures and revenues on a whole program basis and our uncertainties, even detailed indices would yield aggregate approximations. Thus a more detailed industry-by-industry assessment is not warranted until more specific analyses are performed on the projected revenues and costs.

The specific indices used were:

$$\frac{\text{BEFORE TAX PROFIT}}{\text{GROSS REVENUE}} = 0.20$$

TAX BRACKET = 0.50

LABOR INTENSITY (OPERATIONS AND MAINTENANCE) = 0.40

COMPOSITE MEAN SALARY = $17,000 ANNUAL

These figures are typical of various service industries today subject to government regulation. Although profit margin for COMSAT was somewhat higher in the past, the trend has been to force it downward. As discussed in Section 6 of Volume 3, after tax profits have varied from six to fifteen percent typically.

Current corporate taxes are 49 percent. For simplicity, a straight 50 percent was used.

Calculations were performed for two points in time. First, 1985 was selected as a representative near term year where almost all new revenue in SI would be investments. This was assumed to be almost purely public funding (government sponsored development programs). The latter year chosen was 2010, the end of the time period being examined (1980-2010). The revenue in 2010 is projected to result almost entirely (>95%) from sales of Services, Products and Energy (People in Space revenues are insignificant compared to the others).

8.1.2 Results

Jobs and taxes generated were estimated for three programs: the Energy Breakthrough (No SPS), the Baseline (with SPS), and the Upside (all initiatives). Although the Upside is considered the least likely of the three (requiring heavy investment in the early eighties), it was desirable to assess the potential impact of such a strong, aggressive set of initiatives. The results were as follows: (For comparison with the companion Rockwell International report on SI, the NO SPS corresponds to Plan C, BASELINE to Plan A. An UPSIDE type program was not addressed by RI.)

	NEW JOBS*		
	NO SPS	BASELINE	UPSIDE
1985	15,000	100,000	120,000
2010	1,000,000	1,900,000	3,800,000

	TAXES GENERATED*		
	NO SPS	BASELINE	UPSIDE
1985	$ 100M	$ 800M	$ 1000M
2010	$10,000M	$ 20,000M	$40,000M

* DIRECT ONLY. U.S. MARKETS ONLY

The estimate of jobs for 1985 is probably low by a factor of two since most funding would be to the aerospace industries. The Aerospace Industries Association (AIA) has estimated that about 30 direct jobs are created for each one million dollars of appropriation. Direct plus indirect jobs are estimated to total about 100 jobs per one million dollars. Thus the job projection for 1985 is conservative since the computation was the same as for 2010. The true impact on new jobs is some two to four times the numbers shown here depending on specific assumptions and economic theory applied.

In the aggregate, the best guess is that 75% or more of the postulated SI initatives revenues will be job creating in the nineties and beyond. Thus for a workforce of 100,000,000 in 2010 some three to twelve percent could be employed in new jobs created by space industrialization.

The tax revenue calculations take into account corporate taxes based on previous assumptions plus personal income taxes of direct employees. A national composite rate of 0.26 for federal and state income tax was applied to personal income.

8.2 SAMPLE INDUSTRY COMMENTS AND RECOMMENDATIONS

Industry representatives involved in private enterprise in the three major categories (Information Services, Energy and Products) were contacted. The purpose was to obtain information on how government and industry could cooperate and complement in order to make space industrialization grow.

The contacts consisted of:

Information Services - two contacts in the satellite communications business.

Energy - two contacts in power R & D
- two contacts in the investment community

Products - nine contacts in non-aerospace manufacturing

At present a corporate leader/manager cannot justify any investment in products (at the basic research stage and having much too high transport costs) or energy (overwhelming techno-economic risk). The more expensive communications systems (such as the Orbital Antenna Farm of Morgan and Edelson, COMSAT) are being looked at rather seriously, although the total capital and payback times on larger systems look doubtful (see Section 6, Volume 3). One simple message is certain. As techno-economic risks come down, U.S. industry will steadily increase its allocation of resources to SI if a reasonable payback can be obtained. "Reasonable payback" will vary broadly based on initial investment, near term vs. long term risk, guarantees, etc.

8.2.1 Industry Views on Roles and Responsibilities

The specifics of appropriate roles and responsibilities which could be adopted by industry and government vary broadly according to the industry and the individual. It is possible, however, at the rather gross segregation level presented in Figure 8-1 to assemble a set of consensus opinions. As might be anticipated the communications industry is sufficiently mature that the Product Development and Pilot Operations areas require consideration of specific proposals to obtain a particular opinion. The large geo platform concept was one initiative that generally fell in the joint venture category

INDUSTRY IDEAS ON ROLES & RESPONSIBILITEIS

C — COMMUNICATIONS
E — ENERGY
P — PRODUCTS

	GOVERNMENT ACTIVITY	INDUSTRY ACTIVITY	JOINT VENTURE	GOVERNMENT REGULATION
BASIC RESEARCH	C E P			
APPLIED RESEARCH	E P		C	
PRODUCT DEVELOPMENT	E	C*	C* P	
PILOT OPERATIONS	E	C*	C* P	
PRODUCTION OPERATIONS		C E P		C E
TRANSPORT DEVELOPMENT	C E P			
TRANSPORT OPERATIONS		C E P		C E P

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*DEPENDS ON SPECIFICS

Figure 8-1. Industry Views on Roles and Responsibilities for example. A new version of an existing satellite system was considered to be an appropriate industry activity. Particular attention is drawn to the consensus or CEP blocks.

The information presented here is considered as a stage setting providing general guidelines for development of specific arrangement on a case by case basis. Early general agreement to these guidelines by government would encourage enhanced industry involvement in space industrialization.

Specific concerns and recommendations from industry were compiled into a rather extensive list. These are presented in Volume 3.

9. LEGAL CONSIDERATIONS

The legal considerations which must be recognized in any broad examination of space industrialization are, at first glimpse, staggering in their number and complexity. Entire symposia and extensive sessions during various astronautical conferences have been devoted to deliberations on interpretation of existing and proposed agreements, treaties, statutes, etc. In this study, there was no attempt to provide legal interpretations of laws and agreements. Instead, expert opinion was relied on to ascertain the answers to two simple questions: Are there any international laws or agreements which would preclude or severely limit evolution of any of the SI initiatives discussed in this study? Are there domestic laws (in the U.S.) with similar potential for limitation?

At present, space industrialization is not suffering substantially from either international or domestic legal constraints. The large scale initiatives discussed in this report for implementation in the 1980 - 2010 period could all be exercised today within the legal structure. However, all indications are that a series of initiatives to limit the U.S. and its industry are in existence or being originated. A net effect of these in the light of no established national policy in this arena will be to increase economic risk and foster impediment to industry involvement in SI. Without steps to assure industry in these matters, space industrialization may falter regardless of economic and technological enticements.

10. INSTITUTION IMPLICATIONS

A host of institutions ranging from religious to technological will be affected by space industrialization. Their influences on the growth of SI and the specific opportunities which will be capitalized on vary greatly, of course. From discussions with industry contacts, investors, lawyers and national politicians there emerged a basic set of considerations which form the back drop for detailed analysis of key institutional implications.

These items, termed "Five Significant Considerations", are:

1. Space industrialization must become an integral part of national space policy planning.

2. Industrializing organizations and legal structures must evolve and be encouraged.

3. Mechanisms for advantageous transfer of responsibility necessary.

4. The applicability of SI technologies to many problems, needs and markets will go unnoticed without focused dialog.

5. The knotty issues of today in technology export will be further driven by the international/multinational nature of SI.

The government/industry/academic institutional arrangements necessary to accomplish tasks 1 through 3 and optimize benefit from 4 and 5 must be designed in a fashion responsive to the needs of individual SI initiatives. The first steps can be taken, however, by establishing a planning office responsible for the integration of space industrialization elements into all national space activities and plans. This office could supply the data for decisions on items 4 and 5 and formulate plans and focus for accomplishing items 2 and 3 as well as continually project, monitor and assess the implications to a broad family of institutions. Such data should prove invaluable to government and private decision makers alike.

11. CAPITAL REQUIREMENTS AND ECONOMIC VIABILITY

From the revenue analyses reported in Volume 2 of this report it appeared that substantially increased interest in SI might be forthcoming in the investment community. Such interest would result not only from revenue potential but also from initial investment, cash flow, pay-back time, project rate of return and similar considerations. Although such analyses were desirable in all industrial areas considered (Information Services, Energy, Products and People in Space) certain limitations and pertinent factors had to be recognized. Specifically, the rapid developments in evaluations of the economics of space based power, the lack of detailed knowledge on product characteristics, and the dependence of People in Space activities on development of other industries precluded reasonable economic assessments in this study. Thus Information Services was the industrial area selected for assessment of these more detailed economic factors.

Five initiatives in Information Services represent over 90% of the potential domestic revenue from space in Information Services (see Section 5.8, Vol 2). These are:

1. Portable Telephone
2. Teleconferencing
3. National Information Service
4. Direct Broadcast TV
5. Electronic Mail

The large potential market for these services was taken as a natural indicator of private investment potential.

The first multi-use Geosynchronous Platform to provide market entry into the five services is shown in Figures 11-1 and 11-2 (courtesy of Rockwell International). This design provided the basis for development and initial operational cost assessment. As the markets develop into the 1990s and beyond, larger versions of the same type system were assumed.

The specific functions provided by this early satellite are as follows:

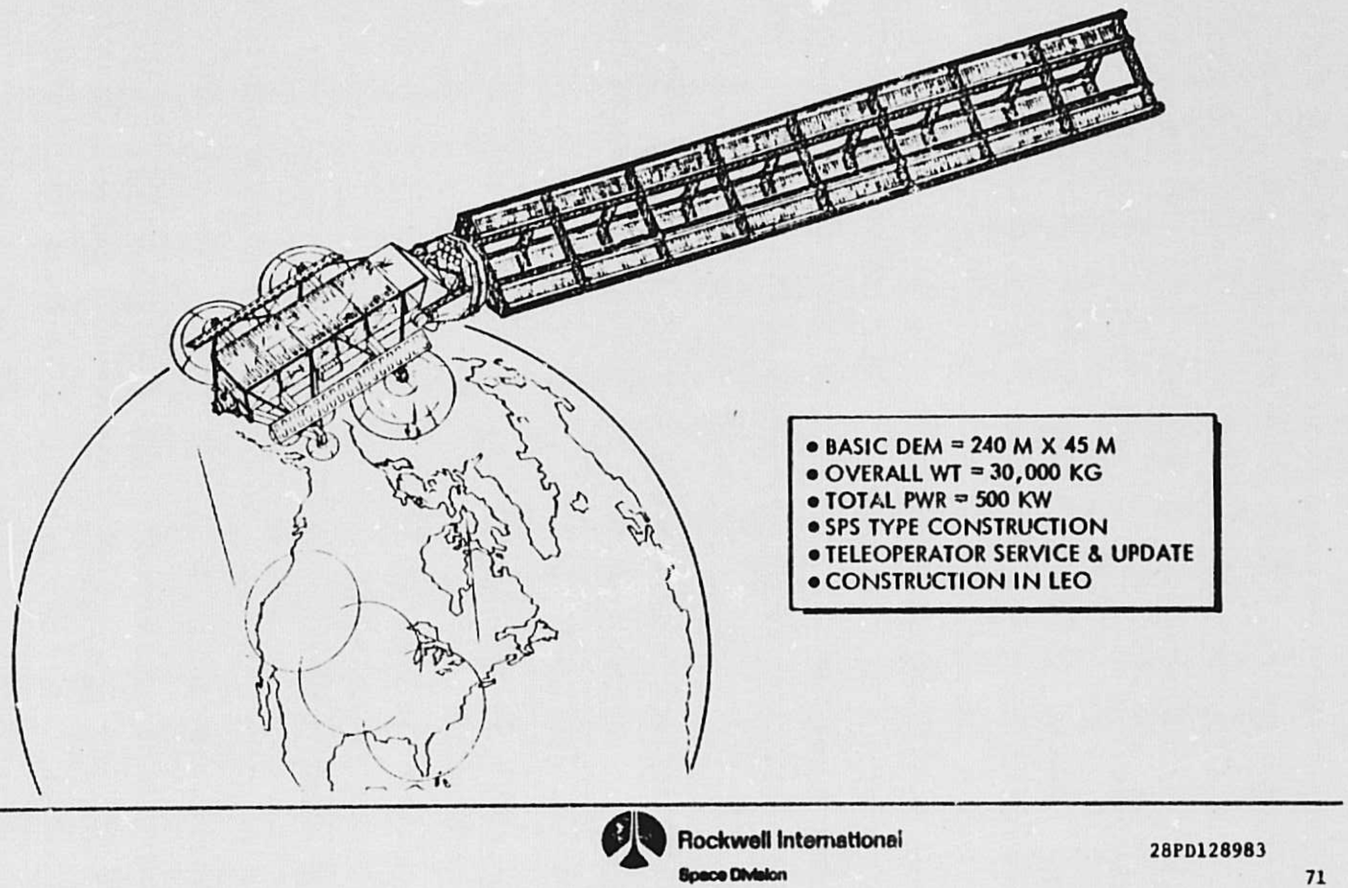

Figure 11-1. 500 KW Geosynchronous Platform

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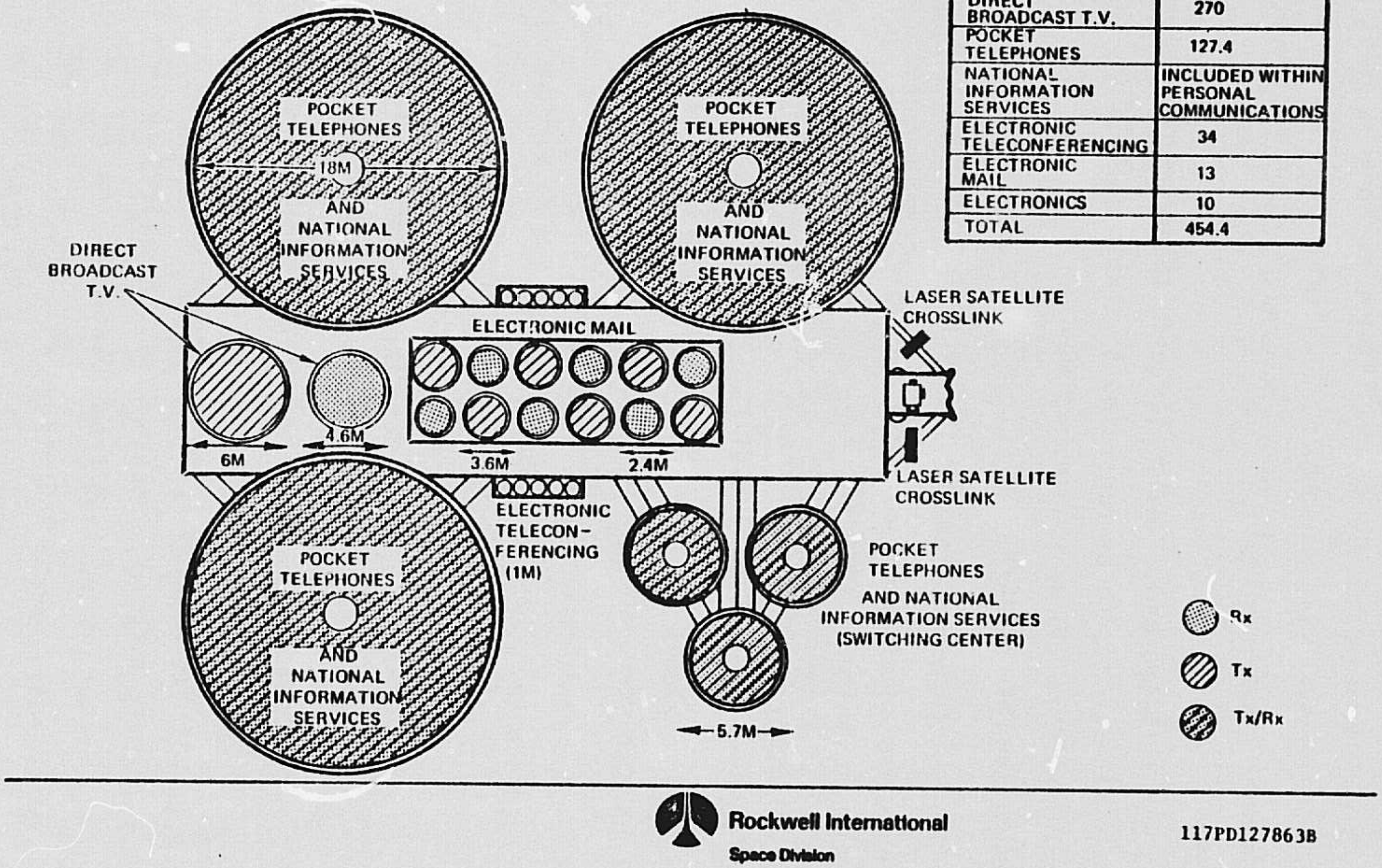
POWER REQUIREMENT

SERVICE	POWER (KILOWATTS)
DIRECT BROADCAST T.V.	270
POCKET TELEPHONES	127.4
NATIONAL INFORMATION SERVICES	INCLUDED WITHIN PERSONAL COMMUNICATIONS
ELECTRONIC TELECONFERENCING	34
ELECTRONIC MAIL	13
ELECTRONICS	10
TOTAL	454.4



Rockwell International
Space Division

117PD127863B

Figure 11-2. Antenna Locations for the Geosynchronous Platform

The specific functions provided by this early satellite are as follows:

1. Direct broadcast television - Five simultaneous color video channels 16 hours per day to be received on modified, conventional TV receivers. The entire CONUS area is to be covered (excluding Alaska, Hawaii, and Puerto Rico).

2. Pocket telephones - Multiple voice channels originating from remote, wireless extensions; to be connected to conventional fixed terminals or other remote terminals via satellite. Saturation capacity to be at least 45,000 simultaneous transactions.

3. National information services - Direct access via satellite from home or business *intelligent terminals* to computer-supported data banks, such as the Library of Congress.

4. Teleconferencing - Two-way (or multiple) video links between as many as 300 ground sites simultaneously (150 conferences). User locations would have studio-type facilities, including multiple cameras and monitors, switch gear, and communications.

5. Electronic Mail - Facsimile transmission of personal and business correspondence. Terminals would be located in regional postal centers. The regional centers would be interconnected via satellite. Each regional postal center would contain equipment to convert hard copy to electronic facsimile, and vice versa. The ultimate goal is to deliver 40 million pages (8½ x 11) from source to destination over night.

Comparisons to current communications industries were made to derive average figures for net profit margin and non-hardware operational expenses. Rockwell International, in the companion study to this one, derived hardware costs related to these five initiatives for the first platform. Using market projections from Part 1 of the SAI study we derived a prediction of channels needed and sized the space systems requirements and estimated production and deployment costs as a function of time. With all the required cost data together a string of projected costs and revenues was calculated.

In the table below, the "Initial Capital" requirement reflects that amount of money required to establish the service and initiate revenue income. "Capital Before Breakeven" reflects the maximum debt incurred (cumulative cash flow) prior to the cash flow break even time when outlay and income balance. "Rate of Project Return" is an investment judgment tool which allows comparison of economic benefit gained relative to other potential investments. A return of 10% would mean that the investor is breaking even relative to a 10% discounted investment. All figures quoted are computed against a positive future scenario assuming needed structures, power and transportation technologies will come to pass.

SERVICE	INITIAL CAPITAL	CAPITAL BEFORE BREAKEVEN	RATE OF PROJECT RETURN
PERSONAL COMM	$420M	$420M	14%
ADVANCED TV	$200M	$200M	17%
NATIONAL INFO	$420M	$620 – $640M	17%
TELECONF	$254M	$2126M	11%
ELECTRONIC MAIL	$4,260M*	---*	—

*STRONG FUNCTION OF ASSUMPTIONS. BREAKEVEN NEVER ACHIEVED FOR POST OFFIC[E] TO POST OFFICE SYSTEM ASSUMED HERE.

The string of costs and revenues are presented graphically in Figure 11-3 with the number of years to achieve breakeven specified. It was not possible in this study to optimize the R&D investment, debt, market penetration rates, technical synergy and other factors affecting these curves. Also, a more aggressive market scenario could easily lead to economies of scale not realized here. Thus we feel the time to breakeven is generally conservative although not unattractive considering the tens of billions of dollars potential annual revenue.

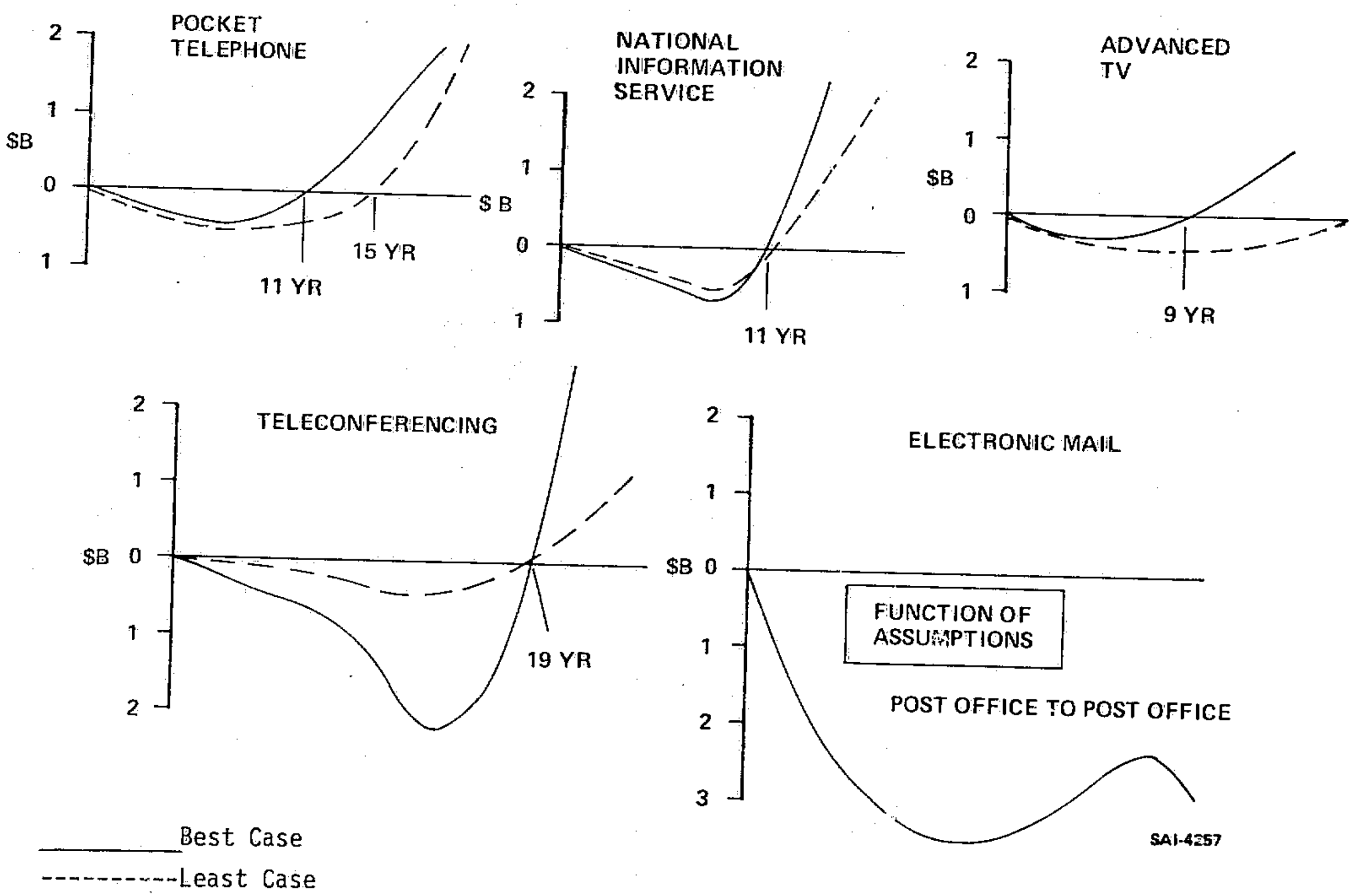


Figure 11-3. Cumulative Cash Flow Requirements

12. OBSERVATIONS AND RECOMMENDATIONS

Many of the results of this study are contained in the various sections of this report as data, observations or conclusions. Recommendations gleaned from outside sources (the industrial contacts) are presented in Volume 3. The purpose here will be to summarize data of particular interest to NASA and the industrial community and present a simple set of recommendations designed to promote the growth of Space Industrialization (SI).

12.1 OBSERVATIONS

Figure 12-1summarizes the How and Why of Space Industrialization. The roles and related activities of government and industry feed the integrated SI activities that represents the summation of all future private and public SI programs. The motivators for such input and sponsorship are shown as a feedback loop. Three encompassing benefits to the public at large are shown as the integrated "value generation" of space industrialization. Net value generation is possible because a new and virtually inexhaustable resource, loosely called "space", is being utilized.

The corollary consideration of What and When are primarily addressed in Volume 2. At the highest aggregation level (general industrial category) the what and when can be displayed as in Figure 12-2. The rather sterile lines on this figure are wholly inadequate to express the latitude that each has according to the scenario assumed and the realities of capitalization and investment. Also the natural or "organic" growth potential of existing space industry (such as Intelsat and COMSAT) are not reflected on Figure 12-2. Thus the potential exists for the curves of each industry to swing toward greater or lesser revenue or benefit. We can say with some confidence that the direction and magnitude of that swing will depend completely on the investments made in the eighties. The technological, legal, institutional, international and regulatory hurdles must all be overcome in concert. <u>The most important, however, is technological</u>. The incentives are sufficiently strong. That, given technical capability, the other hurdles will be overcome. The future of the United States and our system of free enterprise and democracy demand it. Therein lies the challenge to the NASA, the free worlds technological leader in space.

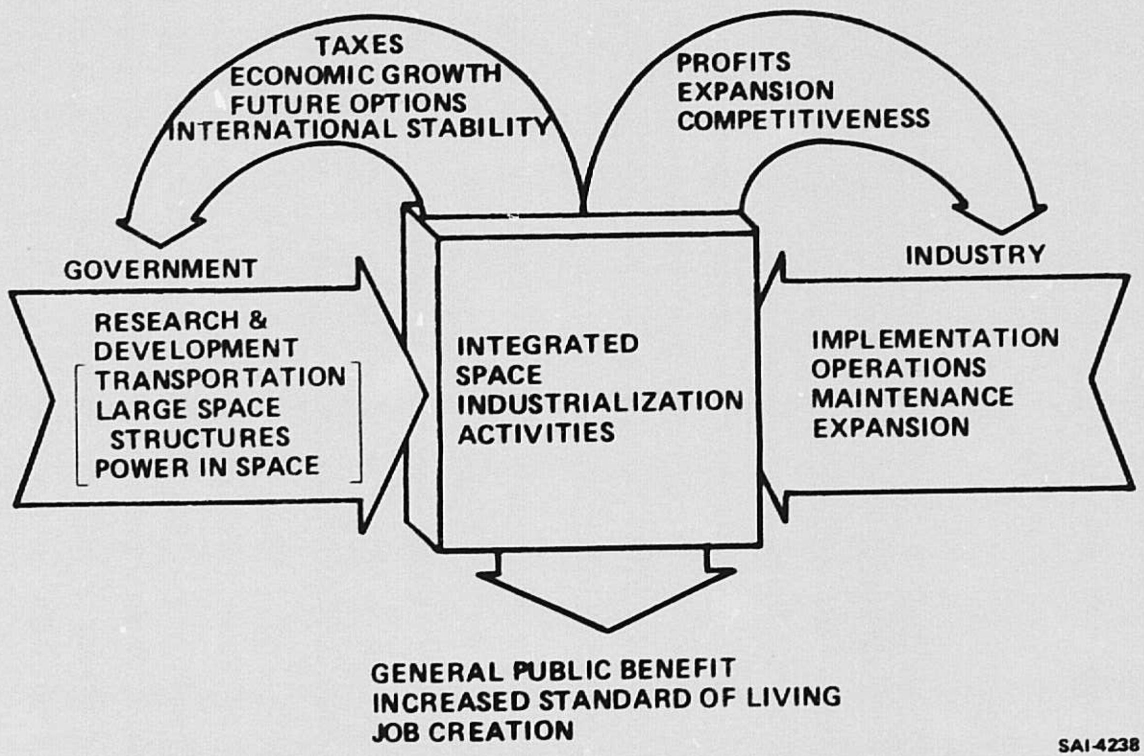


Figure 12-1. The How and Why of Space Industrialization

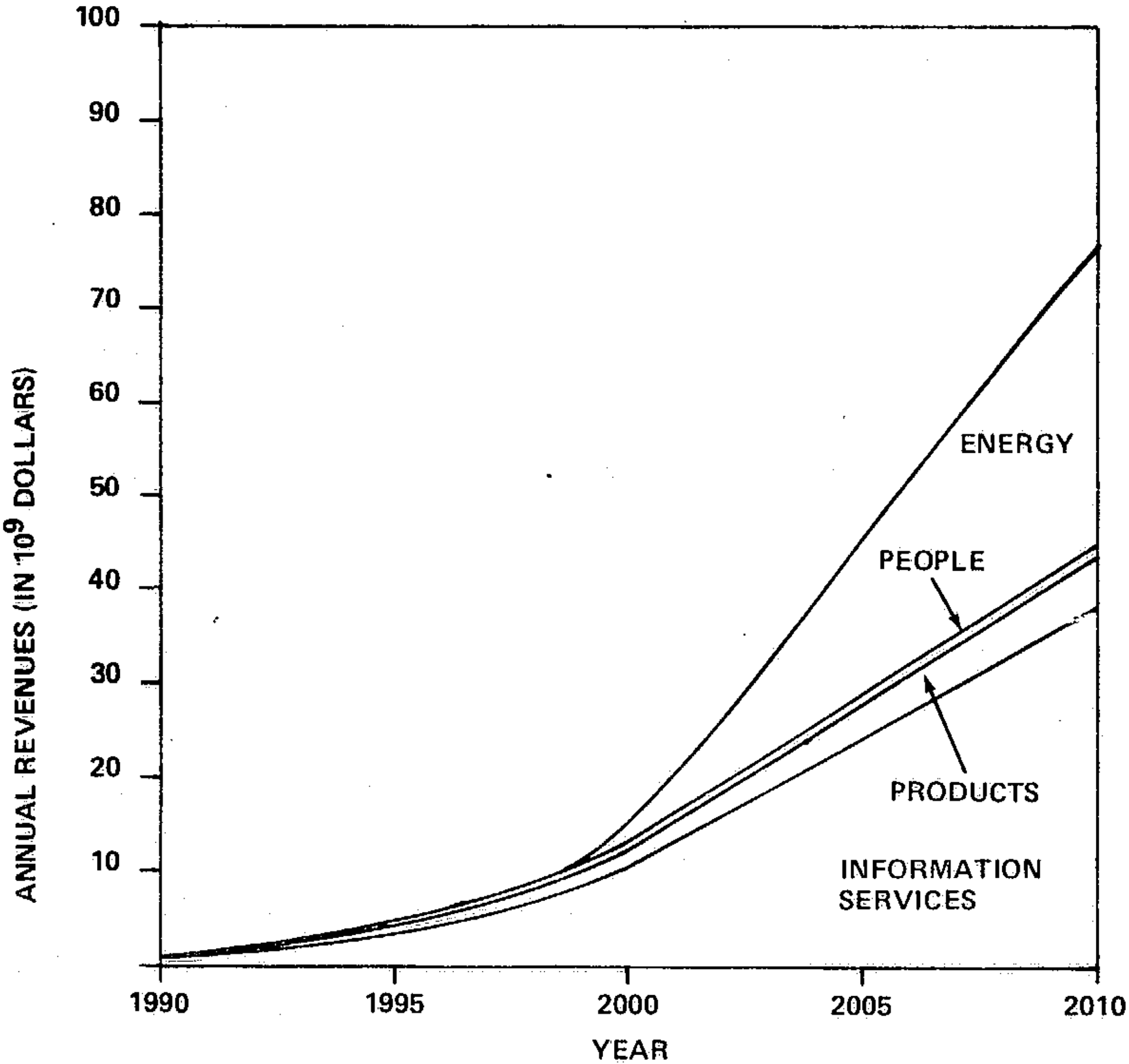


Figure 12-2. The Baseline Scenario Projection of What Space Industrialization Will Be Composed of and When Revenues Will Result

12.2 KEY TECHNOLOGIES

The most important spur to U.S. industry and U.S. world technical leadership will result from development of the following key technologies.

1. Large information systems
   - Structures - Large antenna of 10M to 200 M diameter.
   - Power - 20 KW to 10,000 KW.
   - Data processing - 100 to 1000 times present rate.
   - Transportation to high orbit - routine for maintenance, repair.
2. Materials space processing
   - Laboratory demonstration - goal oriented spar, spacelab.
   - Prototype production - 10 to 100 pounds per day on some products.
   - Orbital support systems - power, structure, stability
   - Low cost transportation to low orbit -<$100/pound to really open market.
3. Large energy systems (use in space, broadcast to earth)
   - Structures - 0.5 KM to 15 KM
   - Power handling - 25 KW to 10 GW
   - Low cost transportation to high orbit - minimum feasible cost.

The projected benefits depend upon commercial operations that can only begin after the key technologies are available. The potential benefits are significant covering a spectrum of national concerns from jobs and balance of trade through standard of living and national pride.

Analysis of future scenarios, markets and resultant programs show that the result will be:

- Millions of jobs created
- Significant national economic growth
- Assurance of a long term favorable balance of trade
- Increased national and world-wide standard of living
- An enrichment of national pride and aspirations
- An invaluable option bank for responding to unforeseen future events

- Increases in knowledge probably unparalleled in the history of civilization

With the shuttle, we have the basis for space industrialization. We can utilize our lead by proper planning and timely implementation. The alternatives are clear---expanding the U.S. economy or face growing international competition.

In summary, the following points support an aggressive coordinated set of space industrialization initiatives in the public and private sectors.

- The revenue potentials exist today--we only lack the systems.
- All industries examined are exportable--the sooner they are available, the sooner we reap the benefits.
- Near term expenditures will create jobs, spur the economy, and be non-inflationary while creating the future.
- The times are right--if we wait they may not be.
- We can not exploit the shuttle if we don't know where we are going.
- Serious international competition is rapidly building.

The U.S. should begin actively supporting space industrialization by producing a major space power system, initiating the development of systems to support orbital manufacturing and developing large information systems. Substantial space power is needed for almost any industrialization. Materials manufacturing in orbit will require considerable demonstration and supporting systems. Large space information systems look the most commercially viable but the orders of magnitude scale-up needed will require demonstration, and legal constraints (e.g., frequency allocations) may prove very troublesome.

This study has shown that commercially viable industries in Information Services, Energy and Products can be realized given the tools illustrated in Figure 12-3 for private enterprise to work with. Our analysis has also shown that public investment in these capabilities in the eighties will be paid back manyfold in the nineties and beyond. All indications are that Space Industrialization is the stimulus required to swing the United States and the world upward toward the next plateau of human

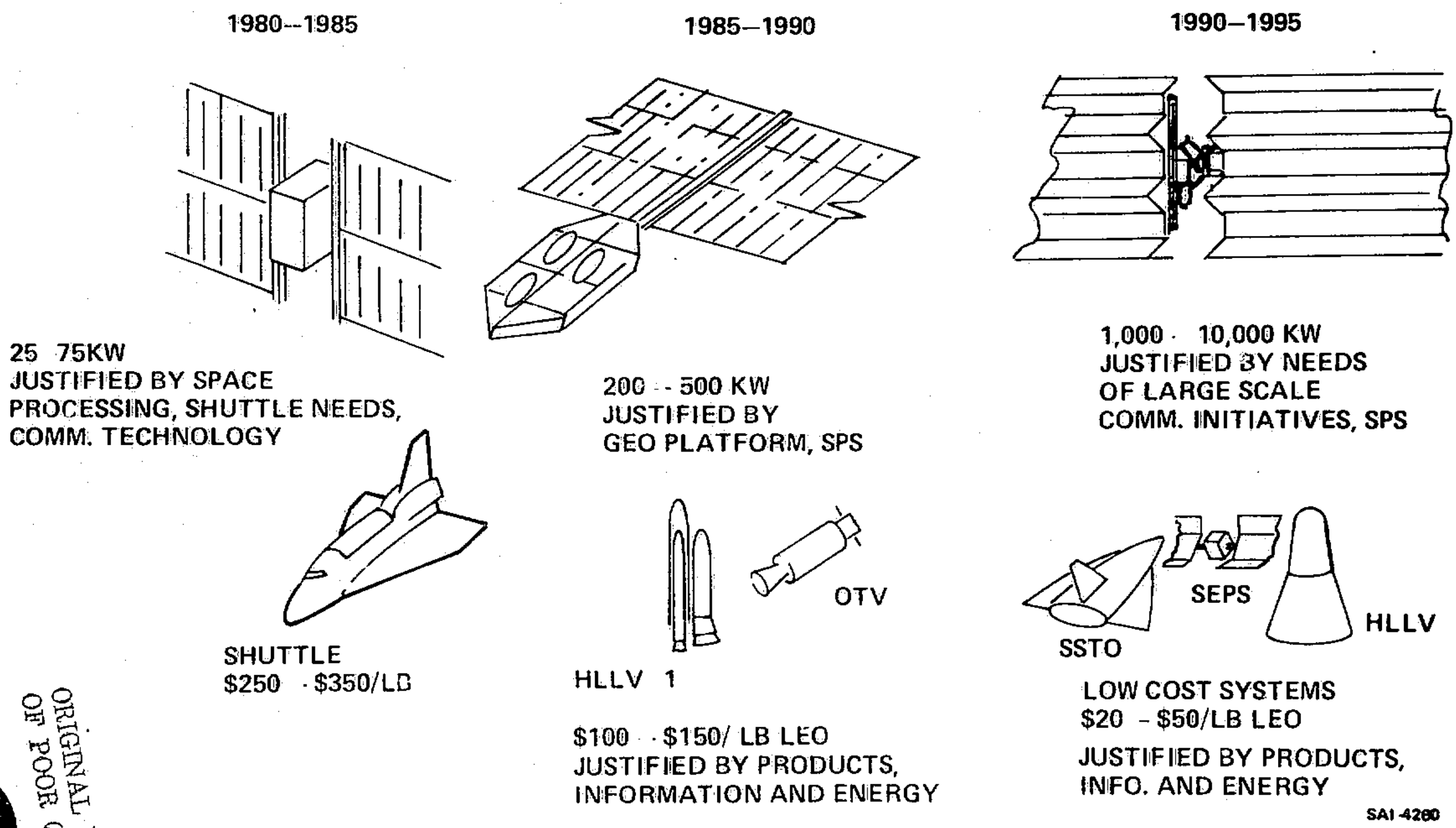


Figure 12-3. SI Structures, Power and Transport Requirements

achievement. This will be achievement in toto, not just in space or on the Earth but throughout the sphere of human endeavor. We believe that implementation of our recommendations and aggressive pursuit of the over-arching concept of Space Industrialization will be concrete steps toward realization of these achievements.

12.3 RECOMMENDATIONS

The following paragraphs contain a series of "key recommendations" that are central to the issue of enhanced SI growth. A broad spectrum of recommendations were formulated, most of them very obvious in derivation. An example might be: "Develop close working relationships with other government agencies and apply SI to their problems and needs." Such recommendations, although central to some aspects of SI growth, are so obviously important that they are already being pursued.

The recommendations presented here, both general and specific, were selected based on their implementation implications. An inherent assumption is that a desire exists to take some predetermined actions to promote the growth of Space Industrialization. Given that assumption, a framework was formulated to provide overall planning guidance and more specific near term steps.

12.3.1 General Recommendations

In the simplest statement, these recommendations are as follows:

- Establish goals for SI in concert with various government agencies and private industry. Most will be in the eighties but some must be identified for the nineties and beyond to obtain overall guidance.

- Plan for the involvement of, and transition to, private industry at the earliest opportunity of all SI initiatives with public services becoming a customer. Consensus opinion is that this will maximize public benefit.

Space Industrialization is, as Ehricke termed it, the overarching concept capable of encompassing and coordinating future applications of space in the most beneficial manner. The individual initiatives in the industrial activities identified in this study should not be pursued as autonomous projects unto themselves. This study has shown that the concepts of Space Industrialization are viable; that synergistic relationships are possible and desirable; and that industry/government cooperative planning and implementation are desirable and feasible. For various reasons industry will be loath to establish long term goals that carry near term investment commitments, thus government must lead in planning. The assumption of authority and responsibility by industry at an appropriate point in the life cycle of an initiative will require operating characteristics that should be established as part of the design and development process. In this area, industry must lead.

12.3.2 Specific Recommendations

- Incorporate in planning and act on all private industry recommendations discussed in Volume 3.
- Establish an office for SI planning, integration and implementation reporting to the NASA Administrator.
- Conduct the series of studies and formulate/implement the plans shown on Figure 12-4. The subjects and sequences are designed to converge on answers to questions delineated here.

The recommendations most strongly expressed by our industry contacts are presented in Volume 3. Although the level of specificity varies, they are all expressions of a positive nature intended to enhance the near and long term growth of space industrialization.

One recurring message has appeared throughout this study when the origins and reasons for success of various projects was examined. It is that three elements were recurrent. They were:

1. The concept was technically sound.
2. Its evolution was well coordinated and the concepts and developments involved widely displayed.
3. Strong advocacy was provided by a small group of well informed, hard working people.

In recent years a fourth element has often been required: application to an immediate need, although there are notable exceptions in recent years in the scientific community. It is these general observations that prompt our recommendation that a special Office for Space Industrialization Planning, Integration and Implementation be established to focus SI efforts.

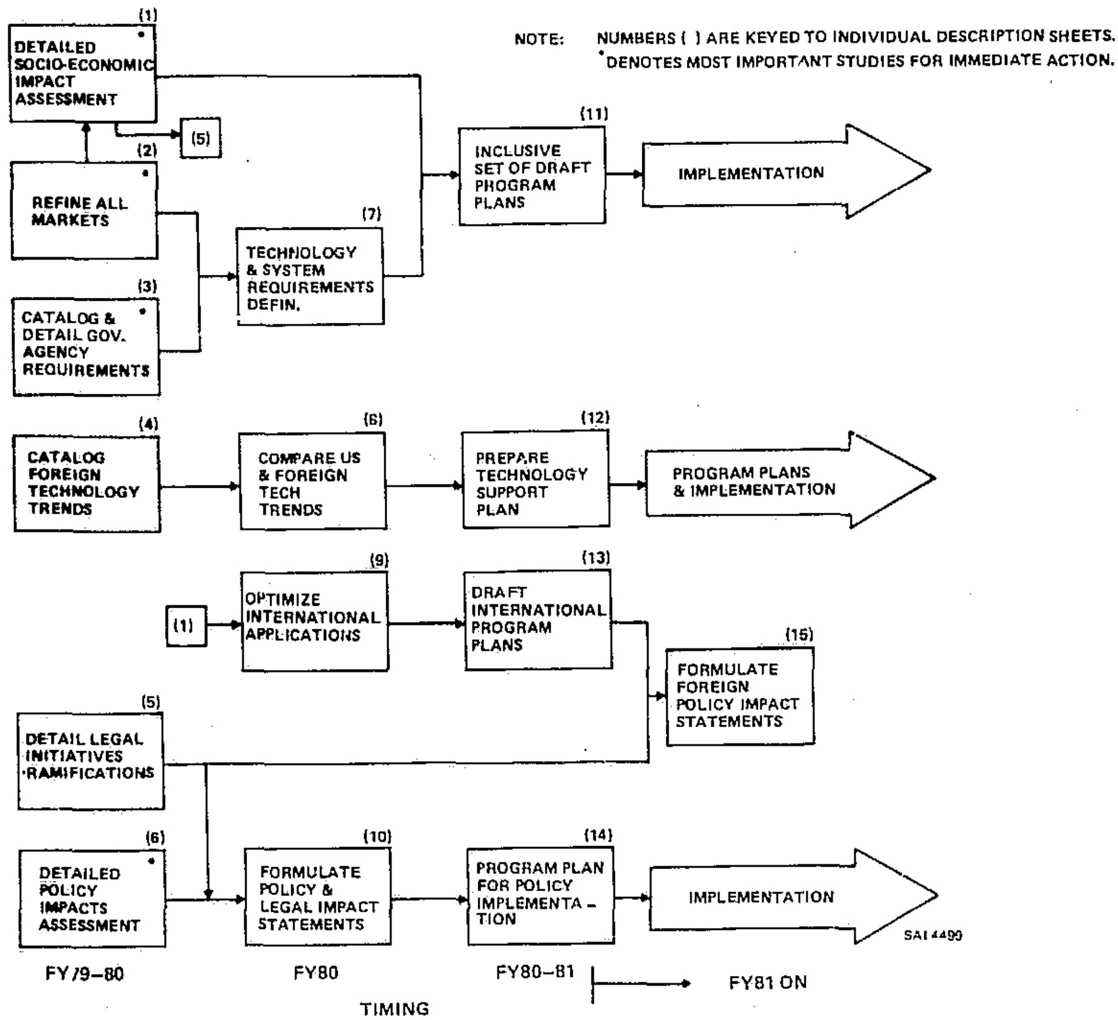


Figure 12-4. Recommendations for Study and Planning Activities Leading to Implementation of SI Programs

Figure 12-4 provides a coordinated view of the individual assessments and planning actions which must come together to promote aggressive SI developments in the eighties. A number in parenthesis with each block keys that activity to the detailed description provided in Volume 3. In column one, certain activities have been marked with an asterisk. This denotes studies and assessments of particular importance which should be initiated first if funding or other constraints preclude addressing all of the FY79 list.

The elaborations in Volume 3 provide not only purpose and description but also duration and level of effort which appear appropriate for each activity. These figures are based on experience and judgment developed during this study relative to the difficulty of addressing a particular subject. Hard charging, positive, aggressive program management is assumed in each case.

The overall implementation concept of Figure 12-4 is sound and proceeds as follows:

First, expend sufficient effort to delineate in detail the requirements and problems.

Second, integrate the requirements and find solutions to the problems.

Third, obtain agreements, funding and policy support.

Fourth, implement the plans and programs.

Fifth, continue planning but maintain long term goals.

The details of Figure 12-4 will undoubtedly change as new knowledge is gained. Without such an overall plan and an orchestration of government involvement in SI the sum of benefits that can accrue to the United States probably will not. It appears that private industry can not step up to the total challenge. If the public sector does not, then we are probably witnessing one of the key non-actions leading to the general demise of the United States as a future technological leader. Unless space begins in less than ten years to generate a highly visible return on investment, we can expect an even greater public disinterest than we have previously experienced. At that point the shuttle will be considered a fraud and the whole concept of Space

Industrialization just another way to flim-flam the politicians into wasting money to keep overpaid bureaucrats on the payroll.

Our perceptions from talks, meetings, newspaper articles, etc. from all over the country is that we are being given the "benefit of the doubt". That will not last forever, probably only three or four years into the shuttle era. It will be necessary to extend that horizon to allow the key technologies to mature and really penetrate the commercial applications arena. That time can be gained through two approaches: (1) Implement experimental programs for the early-to-mid-eighties with strong public appeal and visible results. (2) Promote extensive industry/government involvement in every possible area. This will provide evidence that Space Industrialization is real and a genuine goal of the government agencies involved.

Space Industrialization exists and will grow. How rapidly and to what saturation level are the key questions. Acting on our recommendations will assure near optimum growth patterns, benefiting the United States and humankind in general.